Ecobiology of the common castor butterfly *Ariadne merione merione* (Cramer) (Lepidoptera: Rhopalocera: Nymphalidae)

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Abstract. We describe the life history of the common castor butterfly, *Ariadne merione merione*, monthly occurrence and seasonality of early stages and larval performance in terms of food consumption and utilization, and the length of life cycle. Our study was conducted during 2002 in the Andhra University campus at Visakhapatnam (17°42' N, 82°18' E), South India. Field study indicated that *A. merione merione* was in continuous flight and reproduction, with highest densities of early and adult stages occurring during June – September, the time of the entire South-West monsoon. Occurrence of the early stages was positively, but non-significantly correlated with rainfall, relative humidity, temperature and day-length. Multiple regression analysis showed that the effect of any combination of weather parameters on the reproductive activity was less than 40%. The South-West monsoon period probably influenced the reproductive activity by promoting fresh growth of the larval host plant, *Ricinus communis*, which in turn supported development of early stages. *Ariadne merione merione* was exemplified by a life cycle of 27.4 ± 3.57 days (eggs 3-4, larvae 13-18, and pupa 6-9 days) permitting a maximum of 8-9 overlapping generations per year. The values of the nutritional indices across the instars were A.D. 87.02-95.50%; E.C.I. 3.80-20.90%; E.C.D. 4.00-24.08%, measured at 28°C in the laboratory. These relatively high values, at least partially explain the ecological success of *A. merione merione* in the urban environment.

Key words: castor butterfly, *Ariadne merione*, life history, population index, nutritional indices.

Introduction

Of the estimated 20,000 – 30,000 species of butterflies occurring globally, at least 1,500 species occur in India. Several field guides for the identification of the Indian butterflies are available (Wynter – Blyth, 1957; Haribal, 1992; Gay *et al.*, 1992; Gunathilagaraj *et al.*, 1998; Kunte, 2000 and the references therein). A list of the works giving the descriptions of the life histories was given by Pant and Chatterjee (1950), of which those of Bell (1909 – 1927) are important. However, review of these early works indicated that for many species data, particularly on the duration and phenology of early lifestages, are either absent or incomplete. Haribal (1992) noted that the life histories of nearly 70% of the Indian species require description. We began studies to address the situation. Here we describe the life history of *Ariadne merione merione* (Cramer), the common castor butterfly, of the Oriental region. It is a specific pest of the castor seed plant *Ricinus communis* (Nayar *et al.*, 1976) and the larvae also feed on the stinging nettles *Tragia involucrata* and *T. plukenetti* (Euphorbiaceae) (Kunte, 2000). Because reproductive efficiency depends on life style and feeding pattern (Boggs, 1981; Slansky & Scriber, 1985; Muthukrishnan & Pandian, 1987), we also studied larval performance with respect of food utilization by feeding them on a daily supply of pieces of fresh leaf of the castor plant.

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Materials and methods

The study was conducted during the year 2002 in the Andhra University campus (168 ha) at Visakhapatnam (17°42' N, 82°18' E) situated in the east coast of India. The natural plant community of the campus was searched for the distribution and reproductive activity of the common castor butterfly *Ariadne merione merione* (Cramer). Adult butterflies were seen mostly near the larval host plant *Ricinus communis* Linnaeus. Once located detailed observations were made at 10 sites in order to observe the flight activity and abundance of adults, the period of copulation and oviposition, following which we collected fresh eggs to study the life history and the duration of early stages. After oviposition, the leaf with egg(s) was collected in Petri dishes (15 cm x 2.5 cm depth) and brought to the laboratory. The piece of the leaf with the egg was then placed in a smaller Petri dish (10 cm x 1.5 cm depth) the inside of which lined with moistened blotter to prevent the leaf from drying. Five such samples were placed in a cage covered with wire mesh. The laboratory temperature was 28 ± 2° C and relative humidity 80 ± 10% with normal indirect sunlight conditions that varied in duration between 12h during November/January and 14h during June/July. The eggs were then examined at 6h intervals daily for recording time to eclosion. The larvae were subsequently reared on a weighed quantity of fresh leaves supplied daily. The time of each moult was noted. The morphological characters, body measurements, body weight of each instar and the faeces egested were taken daily. The prepupal behavior of the final instar, pupal particulars and the time of adult eclosion were also recorded. Larval performance in terms of food utilization indices were calculated as described by Waldbauer (1968) as:

$$\text{Food consumption index (C.I.)} = \frac{\text{Wt. of food consumed}}{\text{Wt. of instar x No. of feeding days}}$$

$$\text{Relative growth rate (G. R.)} = \frac{\text{Wt. gained by the instar}}{\text{Mean wt. of instar x No. of feeding days}}$$

$$\text{Approximate digestibility (A. D.)} = \frac{\text{Wt. of food ingested - Wt. of faeces}}{\text{Wt. of food ingested}} \times 100$$

$$\text{Efficiency of conversion of digested food (E. C. D.)} = \frac{\text{Wt. gained by the instar}}{\text{Wt. of food consumed - Wt. of faeces}} \times 100$$

$$\text{Efficiency of conversion of ingested food (E. C. I.)} = \frac{\text{Wt. gained by the instar}}{\text{Wt. of food ingested}} \times 100$$

To determine the developmental success of each of the early stages, a number of eggs were placed in Petri dishes in each month and the number of larvae hatched, pupae formed and the adults eclosed were recorded. To record the different early stages on the natural host plant, one plant at each of the 10 study sites was thoroughly searched at 10 day intervals each month and the early stages found were enumerated and pooled for each month. During the same visits, the flight frequency of adults was also noted using the arbitrary scale of rare, less common, and common. The relation between the monthly distribution of early stages and prevailing rainfall, relative humidity, temperature, and day-length was assessed by statistical correlation and multiple regression analysis using Minitab Statistical Software 14, 2003.

Results

Adult stage (Fig. 1a, b)

Both male and female adults were nearly identical, characterized by their reddish brown colored wings bearing black colored wavy lines. Copulations occurred during mid-day, mostly between 1100 – 1500 h and lasting for more than one hour. Adults were found feeding on spoiled flowers of *Lantana camara*, overripe, fallen and damaged fruits of *Annona squamosa*, *Syzygium cumini* and *Artocarpus heterophyllus*, and the sap oozing from wounds in the tree trunks of *Citrus aurantifolia*.

Egg stage (Fig. 1c)

Gravid females lay eggs singly on the under surface of the leaves of the castor plant mostly before mid-day, between 0900 –1200h. Females spread their wings during egg laying, depositing 1 to clutches of 15. There was no bias for the age of the leaf. During one survey old leaves had 1 – 7 and young tender leaves 1 – 3 eggs. The eggs were round, 0.80 – 0.90 (0.83 ± 0.04) mm in diameter. At oviposition they were white, the color changing to light brown before hatching. When first laid eggs appeared soft in texture, but within 6 – 10 seconds they became hairy. They hatched in 3 – 4 days. Soon after hatching, larvae ate their egg-shells. Each larva passed through five distinct instars over a period of 13 – 18 days.

Larval stage (Fig. 1d-h)

Instar I lasted for 2 - 3 days. Larvae were 1.8 - 2.0 (1.9 ± 0.08) mm on D1, growing to a length of 2.50 - 3.00 (2.80 ± 0.21) mm and width of 0.30 - 0.50 (0.43 ± 0.09) mm before moult. Body was somewhat rectangular in shape, but slightly narrowing posteriorly. Its color was pale brown immediately after hatching, later turning brownish green with three brown colored horizontal bands on dorsal side. Head was very minute, and brown. Instar II also lasted for 2 - 3 days and attained a length of 3.30 – 4.00 (3.73 ± 0.30) mm and width of 0.60 - 0.90 (0.73 ± 0.12) mm. Whitish green spines with branched ends appeared over the entire body. Head was brown with a pair of brown horns. There were no changes in other characters seen in instar I. Instar III lasted for 3 – 4 days. Developing to a length of 6.00 – 8.00 (7.00 ± 0.81) mm and width of 1.10 – 1.50 (1.36 ± 0.18) mm. Dorsally they had a yellowish green broad stripe with brown edge longitudinal to the body. The body spines present on the three brown horizontal bands were also brown. Head was 1 mm in size, blackish brown in color with white markings. The head horns were 0.80 – 1.00 (0.90 ± 0.08) mm long and branched. Legs were clearly visible. The larva did not move much, but moved its head continuously when disturbed. There were no changes in other characters from previous instar. Instar IV also lasted for 3 - 4 days, growing to a length of 10.00 - 15.00 (12.00 ± 0.21) mm and a width of 1.50 – 2.00 (1.73 ± 0.20) mm. Body became green in color. The dorsal stripe turned brown with yellowish cream edges. The three black horizontal bands began to disappear. Head was blackish brown in color, square shaped and measured 1.00 – 2.00 (1.53 ± 0.41) mm in diameter. There were three triangular white markings on the head. The head horns were reddish brown in color and measured 2 mm in length. Segmentation was clear. Body spines were green in color, arranged in four lines on each side of the body on all the segments. The legs were green. Instar V also lasted for 3 - 4 days. When full grown the larva was 23.0 – 30.0 (25.6 ± 0.32) mm long and 2.20 – 3.00 (2.73 ± 0.37) mm wide. Body was dark green. The dorsal stripe changed to orange with black edges showing numerous small white to cream colored spots. The dorsal three horizontal bands disappeared completely. Head was 2.00 - 3.00 (2.56 ± 0.41) mm in diameter. It had prominent white triangular markings with black border two present above and one below. The horns became orange in color, with black tips, and measured 3.00 – 4.00 (3.60 ± 0.43) mm in length. Light and dark green crossed lines developed on both lateral sides of the body. The color of spines changed to brown with black tips and with yellow to orange colored spots at their base.

Pupal stage (Fig.1i)

During the prepupal period of 1 – 2 days the full-grown larva stopped feeding, turned brown and its lateral crossed lines changed to brown and white. The body contracted and the larva attached itself to the substratum with its posterior end hanging downwards. It measured 20.00 – 25.00 (22.60 ± 0.20) mm in length and 3 mm in width. The pupal stage lasted for 5 – 7 days. The brown color changed to black with pupal maturation until adult eclosion. It measured 15.00 – 17.00 (16.00 ± 0.08) mm in length and 6.00 – 7.00 (6.46 ± 0.41) mm in width at the broadest end. The anterior end was narrow. At the broadest point both lateral sides were curved inwards, between which two pointed projections appeared on dorsal side. Average pupal weight was 202.3 mg.

Development success and population index

Hatching success varied between 40 and 100%, being highest during June to September. Both larval and pupal development success varied between 50 and 100%, (Table 1). The numerical frequency of eggs, larvae, pupae recorded on the host plants and adult abundance, along with the prevailing weather data are given in Table 2. The three early stages and adults could be found under natural conditions throughout the year. However, the period of June and September provided the highest frequency of all stages, with peak numbers in July. Correlation between the counts of early stages and monthly average temperature, average relative humidity, total rainfall, and average day-length was positive, but non-significant, the coefficient values being 0.566, 0.333, 0.468, and 0.521 respectively. The four weather variables jointly influenced the distribution of early stages to the extent of about 40%, as indicated by multiple regression coefficients, R^2 0.216 – 0.396 (Table 3). Other combinations including temperature/rainfall-/day-length, temperature/

Table 1. Hatching, larval and pupal development success of *Ariadne merione merione* in the laboratory.

Life cycle stage	Calendar months											
	J	F	M	A	M	J	J	A	S	O	N	D
# eggs incubated	4	4	5	4	5	10	17	10	6	7	5	6
# larvae hatched	2	3	2	3	3	10	17	8	5	5	5	4
# pupae formed	1	2	1	2	3	9	12	8	5	4	4	3
# adults emerged	1	1	1	2	2	9	11	8	4	3	3	3

Table 2. Distribution of early stages of *Ariadne merione merione* on *Ricinus communis* and the associated weather conditions.

Life cycle stage, weather	Calendar months											
	J	F	M	A	M	J	J	A	S	O	N	D
Early stages	7	7	9	8	24	42	117	61	33	21	14	16
Adults	*	*	*	**	**	***	***	***	***	**	**	*
Temperature(°C)	24.15	25.45	27.85	29.15	30.7	29.4	30.75	28.2	29.25	28.3	26.2	24.55
Relative humidity (%)	74	68	74	74.5	71.25	77	73	80.5	76.5	74	62.25	69
Rainfall (mm)	014.1	000.0	000.0	085.2	015.1	143.2	075.4	143.5	023.5	118.4	007.8	000.0
Daylength (h)	1112	1148	1215	1312	1337	1316	1304	1322	1232	1224	1132	1105

* Rare, ** Common, *** Very common.

Table 3. Multiple regression of the counts of the early stages in relation to the prevailing weather parameters.

Constant (A)	X_1	X_2	X_3	X_4	R^2
-229.6	7.342	0.758			0.331
-153.7	6.336		0.139		0.369
-195.5	7.707			0.009	0.321
-7.1		0.338	0.239		0.216
-208.4		0.188		0.183	0.272
-146.2			0.118	0.138	0.297
-137	6.419	-0.270	0.152		0.370
-229.6	9.48	1.094		-0.068	0.335
-87.7	11.88		0.220	-0.183	0.395
-121.1		-0.497	0.137	0.146	0.300
-101.3	12.21	0.301	0.211	-0.196	0.396

X_1 - Monthly average temperature; X_2 - Monthly average relative humidity; X_3 - Monthly total rainfall; X_4 - Monthly average daylength.

Table 4. Food consumption, growth and food utilization efficiencies of *Ariadne merione merione* larva fed with *Ricinus communis* leaves.

Instar number	Wt. of food ingested (mg)	Wt. of faeces (mg)	Wt. gained by larva (mg)	GR (mg/day/mg)	CI (mg/day/mg)	AD (%)	ECD (%)	ECI (%)
I	–	–	–	–	–	–	–	–
II	45.0 ± 10.03	2.0 ± 0.35	1.72 ± 0.16	0.42	11.02	95.50	04.00	03.8
III	150.0 ± 16.39	13.0 ± 2.16	10.85 ± 0.59	0.34	04.80	91.30	07.90	07.2
IV	250.0 ± 05.65	25.0 ± 5.09	31.00 ± 1.65	0.36	02.90	90.00	13.70	12.4
V	925 ± 22.22	120.0 ± 5.88	193.87 ± 2.61	0.45	02.16	87.02	24.08	20.9

– Indicates no data due to very small size of first instar.

Figure 1. Photographs of the sequential stages in the life history of *Ariadne merione merione*. **a)** Adult pairing. **b)** Adults feeding on the damaged fruits of *Annona squamosa*. **c)** Egg. **d)** Instar I. **e)** Instar II. **f)** Instar III. **g)** Instar IV. **h)** Instar V. **i)** Pupa.

relative humidity/rainfall, and temperature-rainfall also had similar to lower values.

Food consumption, growth and utilization:

The data for the weight of food consumed and weight gained by the larvae are given in Table 4. The same data could not be collected for instar I due to its small size with consequent danger in handling. The amount of food consumed increased from instar to instar, the proportion of total food consumed in instars from II to V being 3.28, 10.94, 18.24, and 67.51%. Thus, there was greatest consumption in instar V. The weight gain corresponded to the food consumption trend of the respective instars. The weight gain in instar V was 81.65% of total larval weight. The weight of successive instars plotted against the food consumed indicated a clear relationship between these two parameters (y = 0.227 x and 18.383; r = 0.9963). The values of growth rate (G. R.) decreased from instar II to III and then increased to instar V, the values varying between 0.34 and 0.45 mg/day/mg. Consumption index (C. I.) progressively decreased from instar to instar, the values ranging between 2.16 and 11.02 mg/day/mg. Table 4 also includes the indices of food utilization efficiencies A. D., E. C. I., and E. C. D. The range of A. D. values was 87.02 to 95.5%, that of E. C. I. 3.8 to 20.9% and E. C. D. 4.0 to 24.08%. While E. C. I. and E. C. D. decreased, A. D. increased as the larvae progressed.

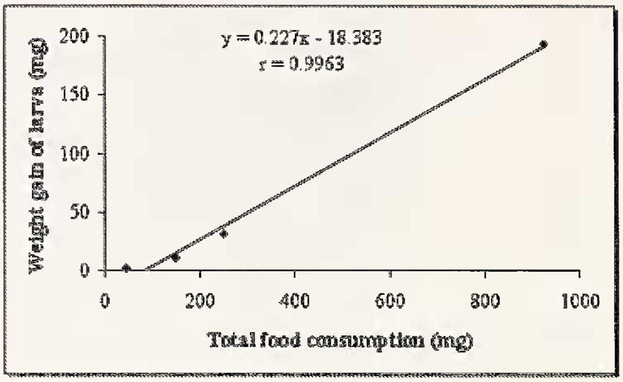

Figure 2. Relationship between food consumption and growth in *Ariadne merione merione* on *Ricinus communis*.

Discussion

The year round occurrence of early stages on the host plant *Ricinus communis* showed that *Ariadne merione merione* breeds continuously, corresponding with the usual pattern noted for most tropical butterflies (Owen, 1971; Owen *et al.*, 1972). The period of highest frequency from June to September correlates with the South - West monsoon. Thus rainfall appears to be the most important factor promoting higher reproduction rates in *A. merione merione* as is the case for both *Catopsilia crocale* (Chirstopher & Mathavan, 1986) and *Catopsilia pyranthe* (Atluri *et al.*, 2004a). However, statistical correlation of the distribution and abundance of early stages with the rainfall, though positive, was non-significant. Precipitation during the South - West monsoon likely had its influence on reproduction via the host plant. During this season, the host plant had its greatest fresh growth, a resource needed by the larvae for better performance due to the likely higher levels of nitrogen and water content (Slansky & Feeny, 1977; Scriber, 1977; Mattson, 1980). Although the host plant was available throughout the year, leaf quality in terms of nitrogen and water content might have varied through the year, hence the observed trend in the pattern of reproduction of *A. merione merione.* The work of Pullin (1987) on the growth of larvae of *Aglais urticae* fed with foliage with different water contents also suggested the likely variations in the breeding success as being due to variations in rainfall. Pollard *et al.* (1997) also examined a similar relationship. The low incidence of early stages during periods other than the South – West monsoon could have been due to a decrease in mature egg number as reported by Braby (1995) in the Satyrine butterflies, which also breed continuously.

Few other species noted at the study biotope also reproduced all year, but at a higher rate during different periods: *Pachliopta arisolochiae* April to May, and October to November (Atluri *et al.*, 2004b), *Papilio polytes* August to February (Atluri *et al.*, 2002), *Graphium agamemnon* August to December (Venkataramana *et al.*, 2003a), *Eurema hecabe* September to November (Venkataramana *et al.*, 2003b), *Euploea core* November to January (Venkataramana *et al.*, 2001). For most of India, Wynter - Blyth (1957) rated spring as the most favorable period, followed by post monsoon and South – West monsoon. In the northern western Ghats, Kunte (1997) observed highest flight activity during late monsoon (August to September) and early winter (October to November). These differences in the phenology of butterflies suggest that different species respond differently to the prevailing environmental seasonality and exhibit different life history patterns. Even different species of a genus may behave differently as observed by Jones and Rienks (1987) in the three species of the tropical *Eurema* they studied.

The overall effect of weather on population trends is complex and difficult to predict, as also expressed by Pollard (1988).

The characters of full grown larva observed in this study substantiate those given in Bell (1910) and Sevastopulo (1939) as well as pupal duration. The total development time from egg laying to adult eclosion was determined as 27.4 ± 3.57 days at about 28°C, thus permitting a maximum of 8 to 9 overlapping broods per year. This behavior is in line with the expectation of tropical butterflies to have a short life cycle, and multiple broods over the year (Owen, 1971). Since temperature influences instar duration and the overall development time (Mathavan & Pandian, 1975; Palanichamy *et al.*, 1982; Pathak & Pizvi, 2003; Braby, 2003), the brood number in other parts of *A. merione merione* distribution may vary from our records depending on the prevailing temperatures. As no temperature extremes occur at Visakhapatnam, especially at the Andhra University site, the duration of life cycle did not vary much over the overlapping seasons.

Adult feeding on the damaged and ripened fruit helps them obtain proteins and carbon sources (Levey & del Rio, 2001), with such nutrient uptake improving egg productivity (Fischer *et al.*, 2004). The larval food also appears to be highly nutritional as indicated by the observed values of assimilation efficiency (A. D.), the efficiency of conversion of ingested food (E. C. I.), and the efficiency of conversion of digested food (E. C. D.) into the body substance. The chemistry of the leaf, particularly its nitrogen and water content, influences the assimilation efficiency (Pandian & Marian, 1986). The castor leaves contain 2.54% nitrogen and 75.20% water (Senthamizhselvan & Murugan, 1988). Hence the observed high A. D. value, mean 90.97%. Such high values are characteristic of the foliage feeders (Slansky & Scriber, 1985) and indicative of their high growth efficiency (Singhal, 1980). The values of E. C. D. and E. C. I., particularly those of the last two instars, are also relatively high (12.4%, 20.9%; 13.7%, 24.1%), thus respectively indicating tissue growth efficiency and ecological growth efficiency, which enabled *A. merione merione* to thrive successfully in the urban environment.

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